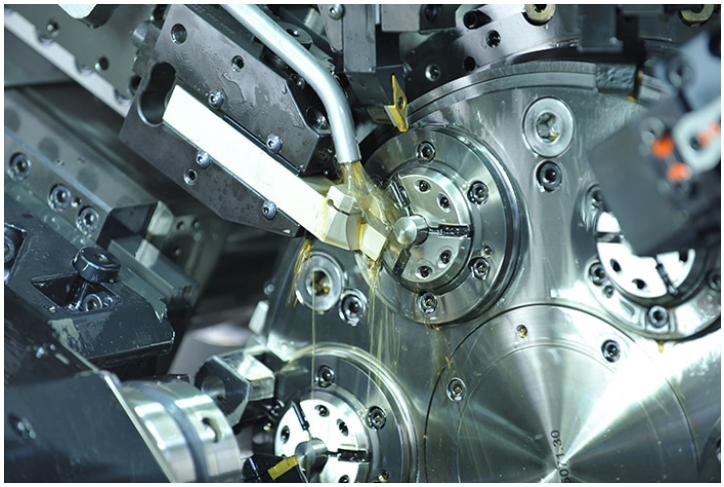
One Spindle, Two Spindles, Three Spindles, More?

October 4, 2019 by Ed Sinkora - Contributing Editor

There are seemingly endless variations in how milling and turning machines are equipped, including mill-turn and turn-mill combos. But one of the basic ways to differentiate between machine tools is by counting spindles.

In lathes, the primary spindle holds the part and it's common to have more than one. In mills, the spindle holds the cutting tool and most machines have just one. What are the tradeoffs that have driven these choices and are they changing?



An Index MS lathe simultaneously machines on six independent part spindles (three visible here). The spindles rotate in a drum so each station attacks the part in turn, producing complex forms in seconds. (Provided by Index Corp.)

When it comes to lathes, there are probably only three situations in which a single-spindle configuration is the right choice. The first is easy: parts that can be completed from one end. But according to Phillip Judt, applications engineer at Absolute Machine Tools Inc., Lorain, Ohio, the problem is that there aren't many such parts. So these machines end up being labor intensive if users are forced to re-clamp parts that require machining on both ends. This points to the second reason for buying a single-spindle machine: budget.

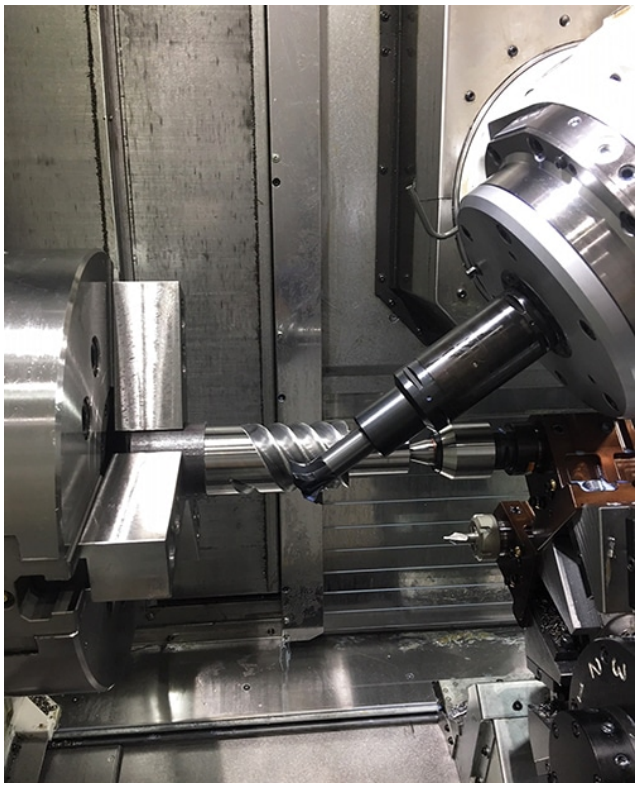
Lathe Spindles and Economy

added, the price difference between a single-spindle and a multi-spindle lathe "isn't that big anymore, especially when factoring in labor."

After all, the simple addition of a sub-spindle provides the ability to machine all six sides of the part without handling it. (The sub-spindle grabs the part before cut-off and holds it for subsequent machining.) And if the parts require cross-drilling or other non-turning complexities, the argument for the newer multi-function lathes becomes compelling.

As Judt put it: "My twin-spindle machines costs a lot less than two or three or four single-spindle machines and a vertical machining center." It is not an unfair comparison because the LICO twin-spindle to which he refers doesn't just have a sub-spindle that holds the part to machine the "other end." It also features three or four independently programmable cross-slides mounted around the main spindle and a turret with live tools for side drilling and milling.

"You can have five independently engaged tools while the part is being held in the main spindle and then cut it off and move it to the sub-spindle and then engage one tool at a time," explained Judt. That makes fast work out of complex parts.



Okuma's MULTUS has a true milling spindle on an articulating B-axis for full five-axis machining. A turret station can be used as a tailstock, as shown here. (Provided by Okuma America Corp.)

The general trend in manufacturing is toward finishing parts with one setup and minimal handling, affectionately referred to as "one-and-done." The drive towards mass customization is a key reason, observed David Fischer, lathe product specialist at Okuma America Corp., Charlotte, N.C. "Part numbers that used to last a decade now last for a year at best," he said. "There are constant design changes and constant upgrades. So more and more customers want machines that adapt." The result, said Fischer, is the increasing popularity of lathes with a sub-spindle, Y-axis turrets, and beyond that multi-tasking machines like the Okuma MULTUS.

Fischer said that years ago a common rule of thumb dictated a multi-function lathe only if milling were limited to about 20 percent of total machining time. Now lathe turrets deliver much more power and torque to the live tooling, such that a 50-50 mix of milling and turning is reasonable. On a machine like the MULTUS or the Index G220, the part may as well be prismatic, with cutoff being the only turning operation. That's because these machines feature a "true" milling spindle on an

comparably compact motor spindles. The Index G220 boasts a B-axis milling spindle 53 interface that delivers up to 17 kW of power and 90 Nm torque at speeds up to The HSK 40 option is rated at 11 kW, 30 Nm, and 18,000 rpm.) Contrast that with the live tooling in the turret, which maxes out at 6kW, 18 Nm, and 7,200 rpm. These multi-tasking machines also have large tool magazines for automatic tool changes.

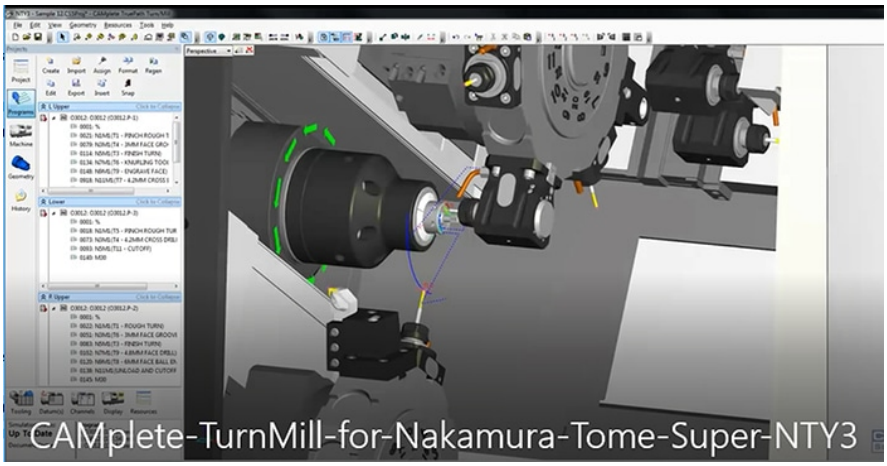
Fischer expressed it well when he said there is "little sacrifice between a lathe and a machining center" on a turn-mill like the MULTUS or the G220. In fact, with the material removal rates of the B-axis spindles and the speed and efficiency of bar feeding, a multi-function lathe is often the best solution for many small milled parts.

How small does it have to be? The Index G220 has a 90-mm diameter bar capacity, the larger G420 goes up to 120 mm, and the Okuma MULTUS up to 4" (101.6 mm). If needed, these machines can also turn and mill larger parts that aren't loaded via the bar feeder. Fischer also pointed out that a turret presents more size limitations and interference concerns than an articulating milling head.

Index refers to its sub-spindle as a "counter spindle" to underline the fact that both spindles have the same torque, power and size. "Sub-spindles are typically a little weaker than the main spindle," said Engel. Index also refers to its twin-spindle machines as "single-spindle" machines as they offer a different approach to multi-spindles (see page 73). It doesn't offer a truly single-spindle machine in the U.S.

Judt said Absolute's team refers to the LICO multi-spindle as a CNC screw machine, which likely helps explain its capabilities to the old timers among us. Finally, Fischer from Okuma said hobbing and gear cutting can now be accomplished on both its turret-type lathes and the MULTUS.

"Gear cutting has typically been done on another machine and it's often sent out to be machined elsewhere," he observed. "It is easy to lose control of the production schedule when parts are sent out and that can rapidly turn into a nightmare. Having that capability on the machine maintains control."



CAD/CAM software helps determine which spindle configuration is most efficient and helps preventing collisions. (Provided by Methods Machine Tools)

High-Volume Turning

The third situation in which a single-spindle lathe might be best is for high part volumes. In such a case, a dedicated set of relatively inexpensive single-spindle machines, each optimized for a specific operation, could balance things out so the cycle times matched. For example, two machines performing a 30-second Op 1 plus a third machine performing a 15-second Op 2. Likewise, milling operations could be performed by separate machines and robots could then transfer the parts between all the units. In effect, this would mean having three or four or more spindles operating on the part simultaneously.

multi-function lathe would require just two sets of chuck-jaws, and even they might hange with a design change. Also, automation in this approach is as simple as using a d having the main spindle hand off the part to the sub-spindle.

Index offers a unique alternative for high-volume parts: MS series turning machines with six or eight (depending on model) independent Z-axis part spindles in a rotating drum, plus one or two counter-spindles, which in this context they call "synchron spindles." A torque motor rotates the spindle drum from position to position in 0.4 seconds (every 60° on a six-spindle and every 45° on an eight-spindle), where it's locked precisely into place by a Hirth coupling. Two independent X-axis cross slides serve each spindle, each with either fixed or live tooling.

In general, a shop would perform the same operation in each spindle position and move the spindle to the next tool set for another operation, and so on, until the front side is complete. Then, the synchron spindle would grab the part, a tool in that spindle position would cut it off, and the machine would then do the end work.

In most configurations the synchron spindles can swivel, providing the ability to apply up to six tools to the back side of the part. There's also an option to add a pivoting Y-axis to the X-axis/Z-axis cross-slides. The control can interpolate this motion along with the spindle's rotation (C-axis) and the linear motion of X to produce a linear Y move to machine flats and other features.

Engel explained that balancing the amount of work for each spindle position is a key consideration for maximizing throughput. "If one spindle position takes 30 seconds and all the other spindle positions take three seconds, the cycle time for that part is 30 seconds. The goal is to have the same cycle time for each spindle position. That's only theoretically achievable, but we often get within a few percent."

The new UNISIG B850 features modern gearing and power train concepts and 166 hp in both the workhead and tool headstocks for deephole drilling in nickel alloys and carbon steels. (Provided by UNISIG)

In fact, average total cycle times for complex parts in this setup range from just 3.5 to 40 seconds. For relatively simple parts, the machines with two synchron spindles can double the output as follows: Do the first operation on parts 1 and 2 in spindle positions 1 and 2, then the second operation in spindle positions 3 and 4, and so on. Conversely, if the part is too complex to be completed on one machine, it is common to bar feed the first machine and then robot load the partially finished parts coming off that machine into the second machine. Although changeover time on any of these configurations is quite short, given their cost the business case depends on the need for high production rates.

CAD/CAM a Vital Tool

Engel from Index strongly recommended using a CAD/CAM package to prevent collisions and optimize the cut.

CAD/CAM can also be helpful in picking the right machine configuration, said Sergio Tondato, product manager for the Nakamura-Tome line from Methods Machine Tools Inc., Sudbury, Mass. "We routinely simulate running a part on different machines and compare cycle times. For example, what is the part output on a twin spindle, single turret? A twin turret? A three turret? And so forth.

o Methods partners with CAMplete in this area. Besides accurate cycle time AMplete software also performs collision checks and makes it easy to change tool . Methods is so keen on the benefits that it includes CAMplete TurnMill with all its Nakamura-Tome multi-turret lathes, an arrangement exclusive to Methods. CAMplete just launched TurnMill V9 that comes with 3D view enhancements, simulation improvements, and revamped post processing support.

Multi-Spindle Milling

For larger parts and most castings and forgings, machining centers are the way to go. And as we said at the outset, the vast majority of these machines have only one spindle. As Index's Fischer explained, "to get multiple tools in a cut on a mill you'd typically use a multi-drill head from a company like Zagar. The machine would load this head to drill a six-hole bolt circle, and then change it out for a conventional tool holder."

So why is there growing interest in horizontal machining centers with multiple spindles? Why are several high tech providers offering them? This list includes SW North America, New Hudson, Mich., and PCI-SCEMM, which is distributed in North America by Absolute Machine Tools.

The PCI METEOR horizontal features two fully independent spindles and can tackle two different parts simultaneously for 30 percent less than two single-spindle machines.

According to SW's calculations, a twin-spindle consumes 36 percent less electricity than a single-spindle for the same output and a four-spindle consumes 52 percent less. But President and CSO Jim Campbell said this doesn't even show up on a buyer's spreadsheet in the U.S. In the U.S., the big benefit of a multi-spindle is maximizing output for a given amount of floor space. SW figures a twin-spindle takes 33 percent less space than a single-spindle for the same output while a four-spindle takes 66 percent less. Campbell said for machining aluminum, the company's twin-spindle will normally replace three single-spindle machines "because of how our fixtures and tool changers are designed and the moves the machine can make all at once. So for a guy who's got a job but doesn't have floor space and can't find people, it's an ideal situation."

Max Paulet, key account manager for PCI-SCEMM, added that its twin-spindle costs 30 percent less than two single-spindle machines. So the numbers are compelling from several perspectives.

Multi-spindles are central to SW's identity and Campbell said that at this point the only single-spindles it is selling are for large battery housings, a new market for everyone. "Owing to its linear drives, this machine will deliver a lot more production than a typical single-spindle," Campbell added. "And these parts require a lot of moves, which is easier with a single-spindle than with a twin-spindle."

SW produces multi-spindle HMCs, such as this W02 twin. (Provided by SW)

The resistance to multi-spindle machining centers stems at least in part from concerns about setup and the fact that having more spindles will naturally apply more force against the worktable and fixtures than traditional machining. The latter is addressed by clever machine construction and Campbell said the supposed setup difficulty is "more of a perceived issue than a real issue. And even if it takes a little time to do, by the time the machines are running they are out-producing what would be made on a single-spindle."

In most cases, these multi-spindle mills are using all the spindles to perform the same operation on multiple parts simultaneously. Likewise, Paulet explained, "the spindles are usually mounted on the same carriage, with one independent axis, which is usually Z. But how to process two very precise parts with such a machine if it is not possible to enter fine compensation on both sides?"

For PCI the answer was making each spindle independent in X, Y, and Z. This enabled fine compensation and high accuracy on each spindle, plus the ability of each spindle to simultaneously machine different areas on the same part. Examples of applying twin-spindles to the same part include machining the right and left side of large chassis parts, like knuckles, and machining a large battery tray, which Paulet said resulted in a nearly 40 percent reduction in cycle time compared to a single-spindle solution.

It's even possible to machine completely different parts simultaneously with PCI's "two machines in one" concept. Paulet said customers are starting to move toward this innovative solution and PCI has already sold a line of twin-spindle machines where a gearbox housing is made on one spindle while the other spindle machines the clutch housing.

SIDEBAR: Deephole Drilling Made Easy

No matter how capable a lathe or machining center, drilling deep holes can be extremely challenging, so challenging that UNISIG, Menomonee Falls, Wis., has a solid business building machines specifically for this application. CEO Anthony Fettig said most of his company's business is in machines that drill holes with a length-to-diameter ratio between 20:1 and 200:1, but they can be the right fit for smaller ratios too if tolerances for bore diameter, straightness, and surface finish are tight.

Another factor, as Fettig put it, is "tolerance for frustration. When gundrilling on a machining center, it is common to break drills, or cut oversized holes, or they drift quite badly, and you don't really

nplishes this with a combination of specialized machine configurations, specialized of course, applications know-how. A key technique for larger diameter bores (20-200 mm) uses BTA tooling. (BTA is an acronym for the Boring and Trepanning Association.) With BTA tooling, the machine blasts high-pressure coolant around the outside of the tool and the chips flow through the tool center and back through the drill tube and machine spindle. The approach is five to seven times faster than gundrilling, but requires higher power.

UNISIG also tackles deephole applications with multiple spindles when warranted. Fettig said UNISIG asks customers about expected part volumes and geometries and then tries to "balance overall efficiency and the convenience of changeover and machine utilization."

Fettig identified three general application categories: "Highly complex parts with lots of holes in the same part, in which case you design the machine to have as many spindles utilized on the part as possible to make the most of it." An example would be a heat exchanger with 5,000 holes.

"The other extreme would be identical, simple parts that just need lots of the same spindle doing the same thing," he said. An example would be identical transmission shafts that each required a 14-mm hole drilled through the center. In this case UNISIG might apply four spindles to machine four parts in each cycle.

The third case, a middle ground Fettig said is quite common, is when sequential operations are required in the same part. For example, a transmission shaft with a stepped bore (effectively two deep holes that are concentric with each other). In this case, Fettig might recommend a two-spindle machine with independent feeds in which each spindle hits the part in sequence, or a twin-spindle in which the part is moved from spindle to spindle. Fettig added that years ago UNISIG would commonly supply six-spindle gang machines, but the trend today is to put a robot between several twin-spindle machines using higher performing tools.

"This yields a great deal of flexibility and very high spindle utilization, because changeover time on a twin-spindle machine is very short and the machines can reconfigure themselves for different work piece lengths and diameters," he said. "And the robot is fast enough to keep up with a two-spindle machine."

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